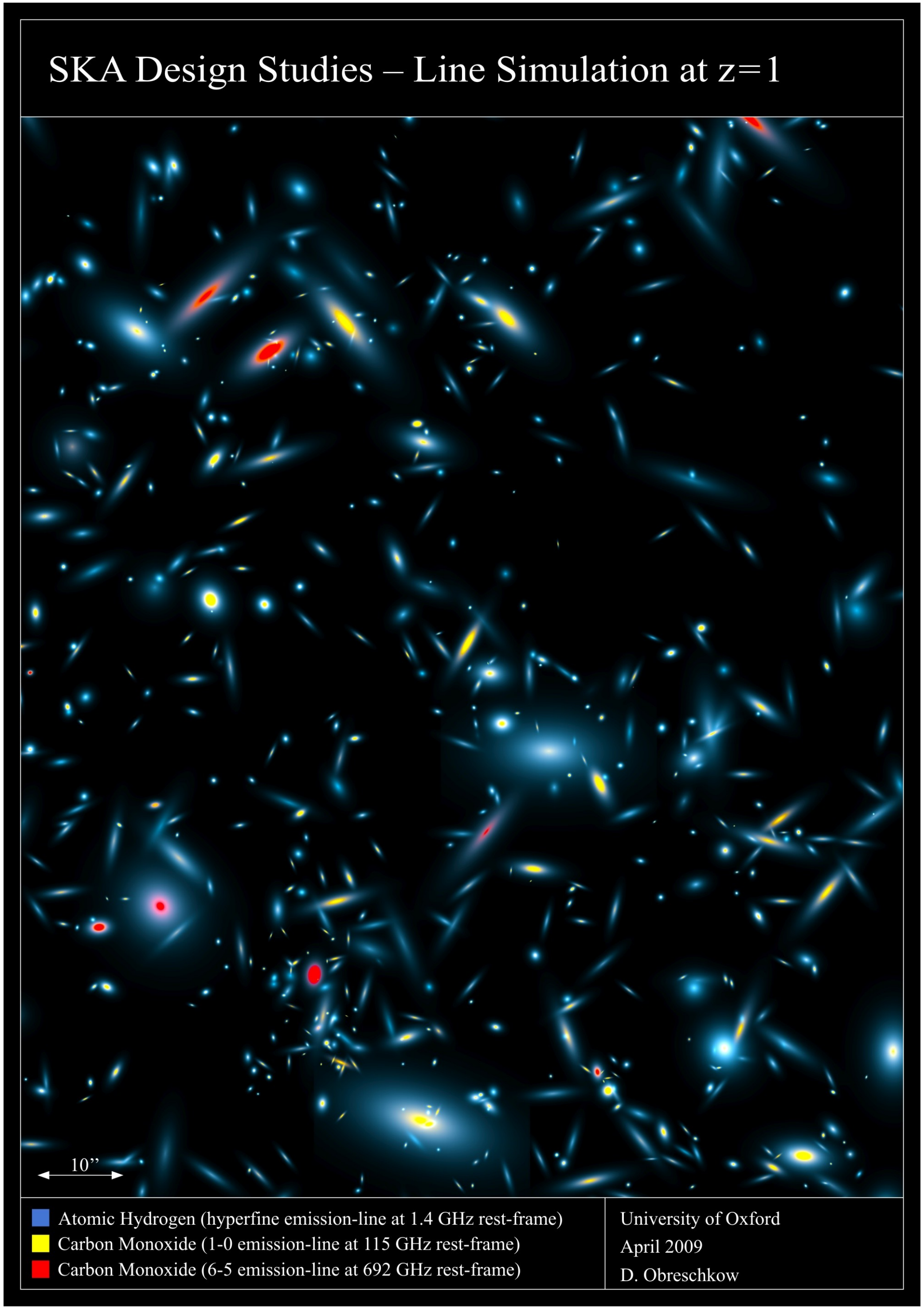


Future Views of HI in High-*z* Galaxies

Andrew Baker
Rutgers, the State University of New Jersey

SKADS team

Outline

This talk will focus on HI at $z \leq 1.4$ seen in emission
(see N. Gupta talk for discussion of absorption).

"HI in high-*z* galaxies" is not an oxymoron!

I. The HI survey wedding cake.

II. Looking At the Distant Universe with the MeerKAT Array
(LADUMA): a 5000-hour survey centered on GOODS-S.

The path to the SKA

Square Kilometre Array (http://www.skatelescope.org/) will be sited in Australia or South Africa.

precursor = “a telescope on one of the two SKA candidate sites, carrying out SKA activity”

ASKAP, MWA, MeerKAT

pathfinder = “SKA-related technology, science and operations activity”

APERTIF, Arecibo, ATA, eEVN, EMBRACE, e-MERLIN, EVLA, LOFAR, LWA, SKAMP

HI in the low-*z* universe: WALLABY

WALLABY: the ASKAP HI All-Sky Survey

PIs = B. Koribalski (ATNF), L. Staveley-Smith (ICRAR/UWA)

With a parallel APERTIF survey, will define an all-sky survey to *z* ~ 0.2.

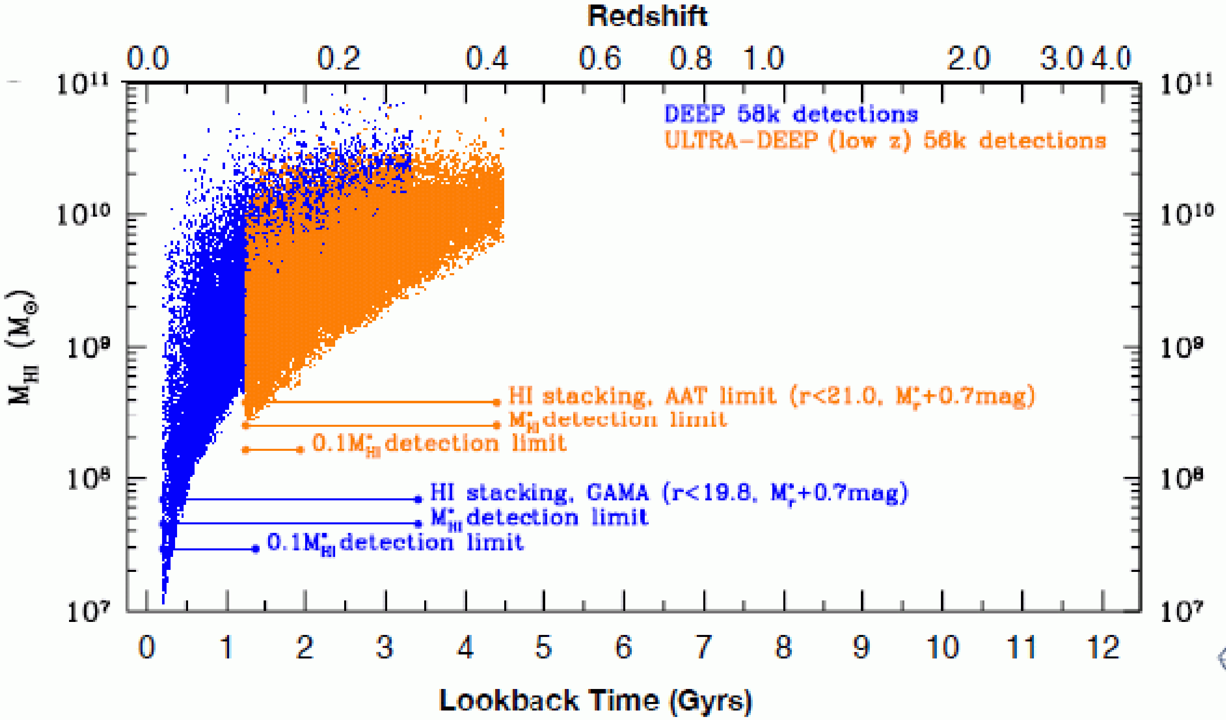
Takes advantage of ASKAP's 36 × 12m dishes, each equipped with a 188-element phased array feed that provides a 30 deg^2 FOV!

HI in the mid-*z* universe: DINGO

DINGO = Deep Investigation of Neutral Gas Origins

PI = M. Meyer (ICRAR/UWA)

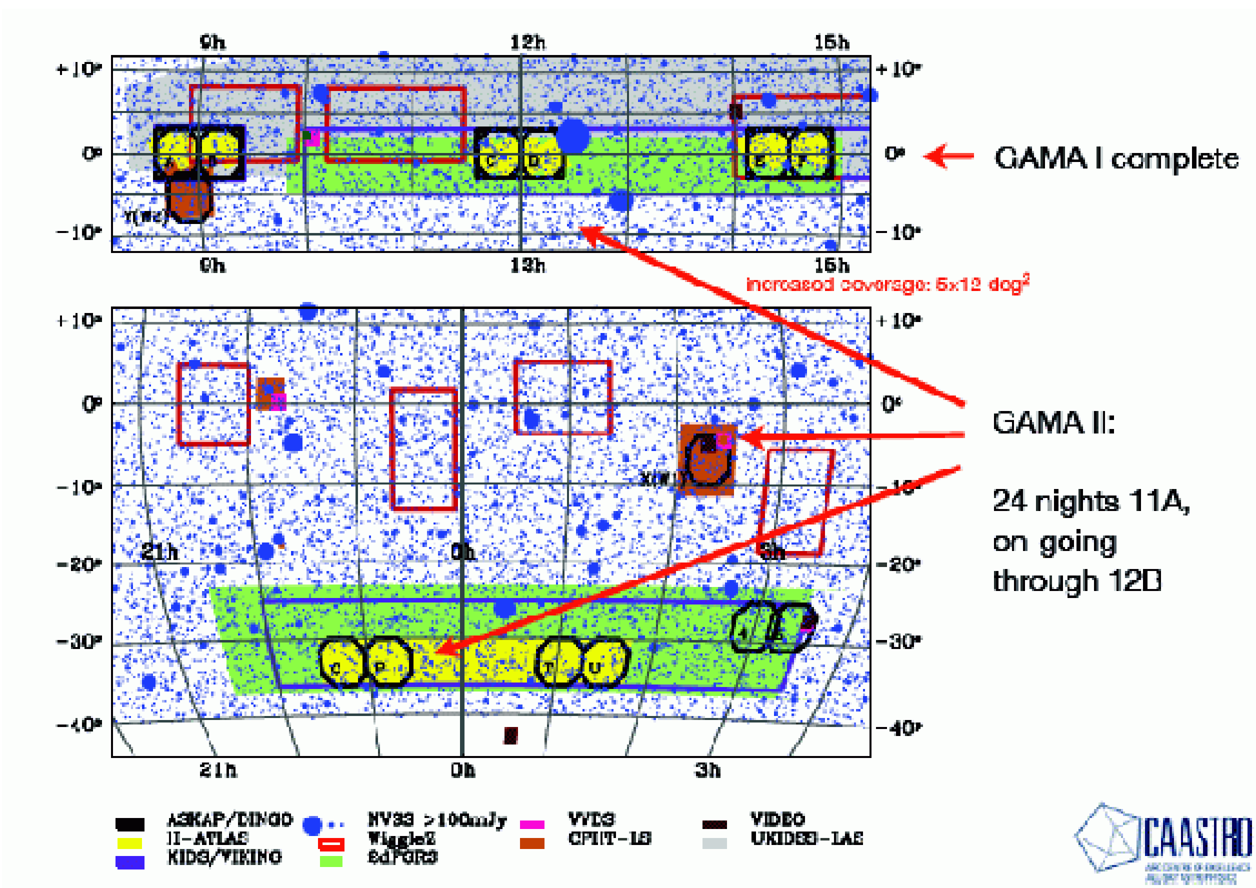
- **Deep**: 150 deg^2, $0 < z < 0.26$, 500 hours/pointing
- **Ultradeep**: 60 deg^2, $0.1 < z < 0.43$, 2500 hours/pointing



EVLA, APERTIF surveys to *z* ~ 0.4 are also in the works.

Stacking in the DINGO fields

DINGO is concentrating on the GAMA fields, which already have extensive optical spectroscopy, in order to facilitate stacking analyses.



Courtesy M. Meyer.

HI in the high-z universe: LADUMA

Looking At the Distant Universe with the MeerKAT Array:

5000 hr survey of single field encompassing GOODS-S + GEMS + Extended CDFS, to z_{HI} = 1.44 (t_{look} = 9.2 Gyr).

See http://www.ast.uct.ac.za/laduma for details.

Three PIs inherited from merger of two proposing teams:

Sarah Blyth

University of Cape Town

Benne Holwerda

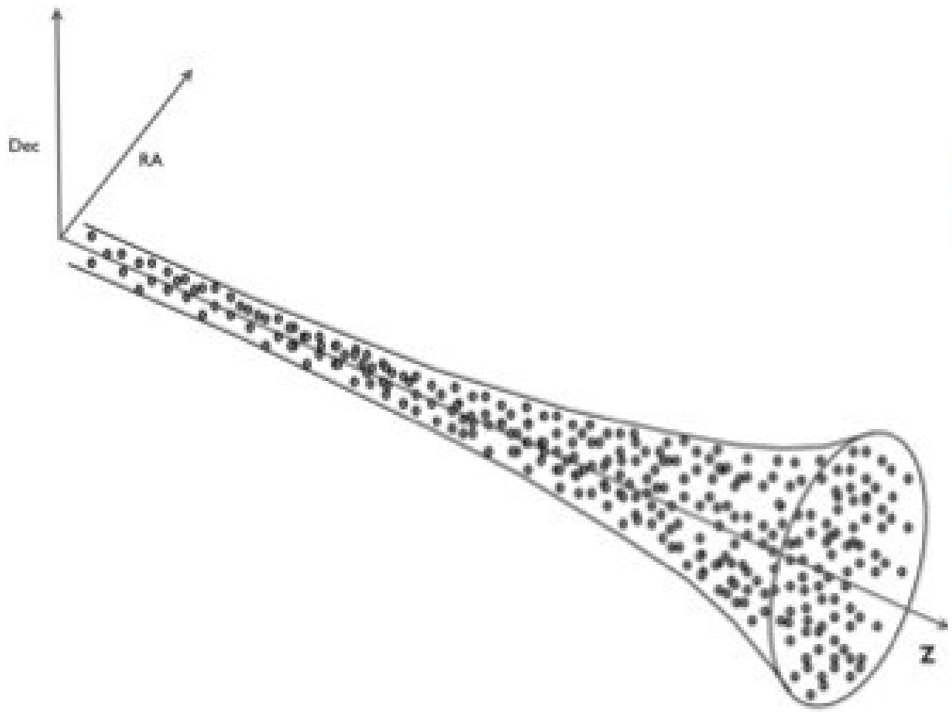
European Space Agency

Andrew Baker

Rutgers University

Why "LADUMA"?

"Laduma!" = "It thunders!" in isiZulu = unique South African exclamation when a goal is scored in soccer.



Thanks to the $\propto (1+ z)^2$ area of MeerKAT's primary beam, LADUMA's data "cube" will be more of a data vuvuzela.

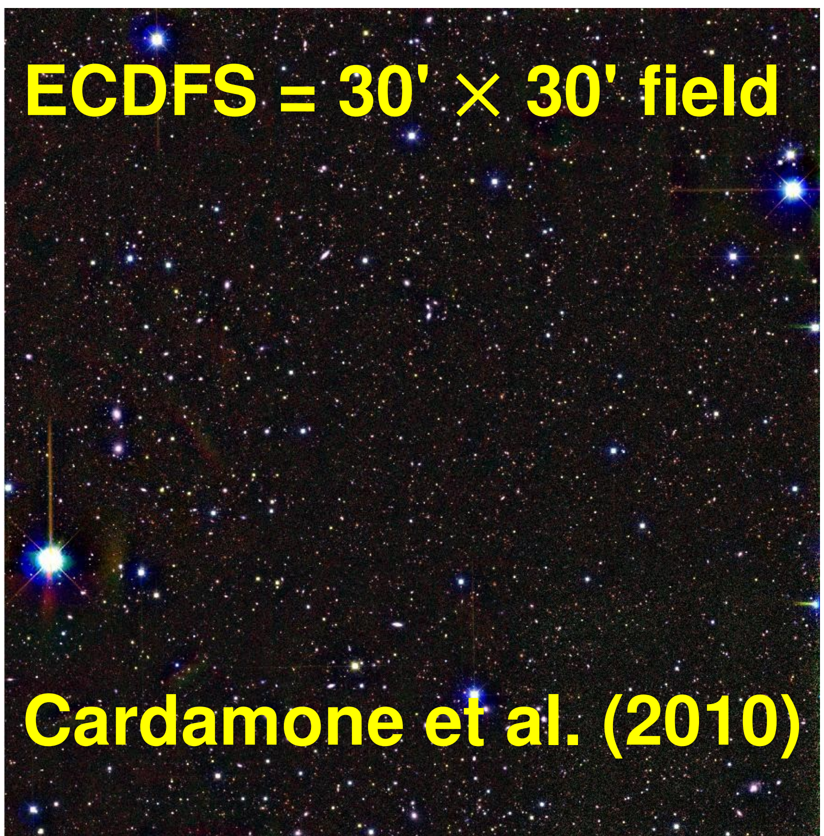
<u>LADUMA team members</u>

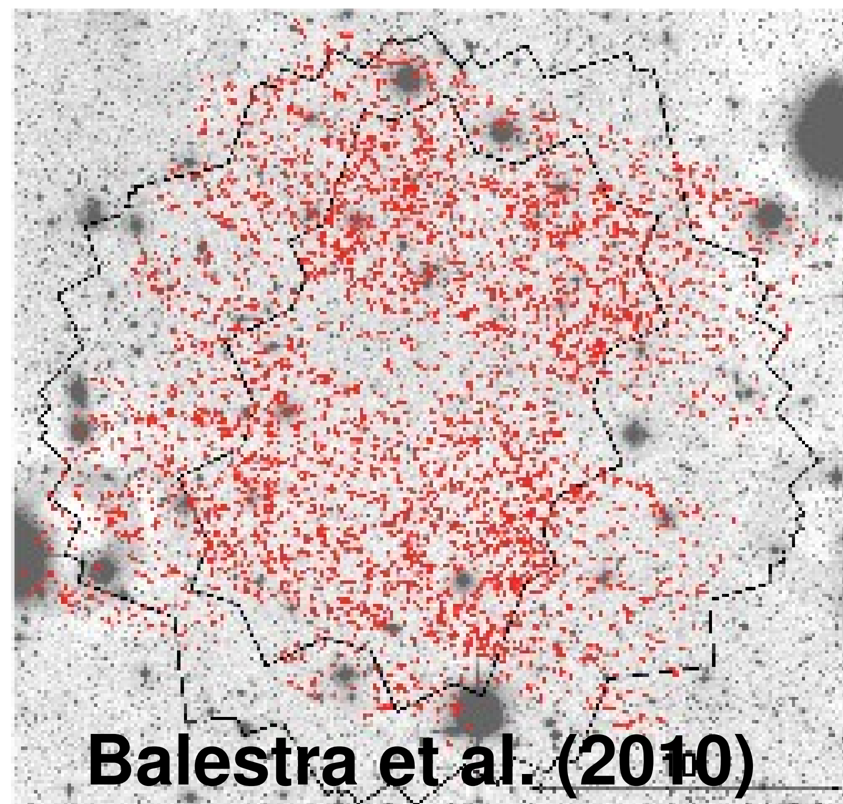
<u>A. BAKER</u>, B. Bassett, M. Bershady, ***<u>S. BLYTH</u>***, A. Bouchard, F. Briggs, B. Catinella, L. Chemin, C. Cress, J. Darling, R. Davé, R. Deane, E. de Blok, E. Elson, A. Faltenbacher, B. Frank, E. Gawiser, T. Henning, ***<u>B. HOLWERDA</u>***, J. Hughes, M. Jarvis, R. Johnston, S. Kannappan, N. Katz, D. Kereš, H.-R. Klöckner, R. Kraan-Korteweg, P. Lah, M. Lehnert, A. Leroy, G. Meurer, M. Meyer, K. Moodley, R. Morganti, S.-H. Oh, T. Oosterloo, D.J. Pisano, S. Ravindranath, S. Rawlings, E. Schinnerer, A. Schröder, K. Sheth, M. Smith, R. Somerville, R. Srianand, L. Staveley-Smith, I. Stewart, P. Väisänen, K. van der Heyden, W. van Driel, M. Verheijen, F. Walter, E. Wilcots, T. Williams, P. Woudt, M. Zwaan

Target field: ECDFS (and beyond)

GOODS-S ⊂ GEMS ⊂ MUSYC/ECDFS ⊂ LADUMA footprint:

- **+ > 4500 spectroscopic redshifts in inner 30' × 30'**
- **+ fully imaged at 250/350/500μm (BLAST) + SWIRE bands**





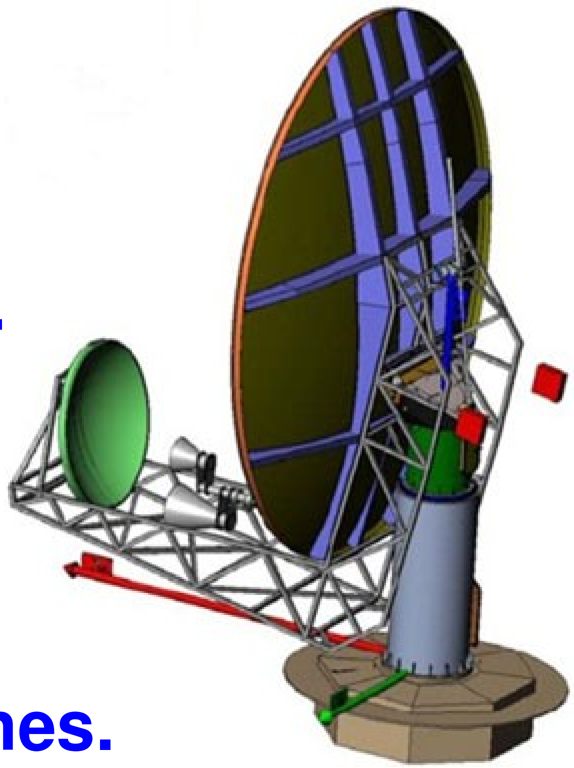
MeerKAT: key specifications

See http://www.ska.ac.za/meerkat/ for full details.

Antennas:

64(+7) $\times$ 13.5m offset Gregorian.

Primary beam = 0.8 $\times$ (ν/1.4 GHz)$^{-2}$ deg^2.



Configuration:

70% of antennas on 29m–1km baselines.

30% of antennas extending to 8km baselines.

Resolution: depends on taper; 40” gives best S/N+beam.

2018+: 7 additional antennas out to 20km baselines.

MeerKAT: frequency coverage

Phase 1 (2016+):

1.00–1.75 GHz

... corresponds to $0 \leq z_{HI} \leq 0.42$.

Phase 2 (2018+):

8–14.5 GHz

0.58–1.015 GHz

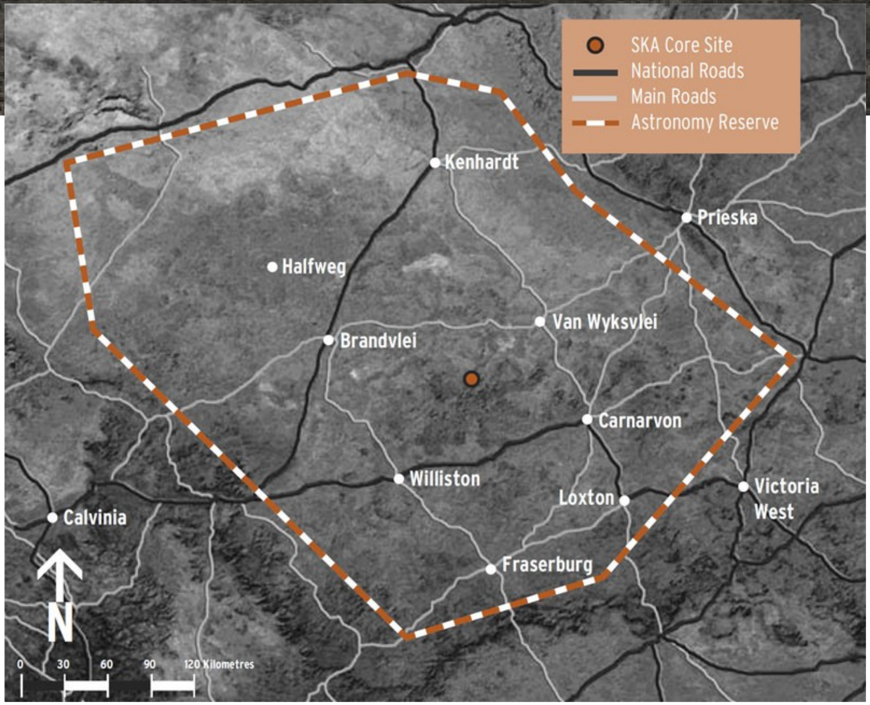
... of which latter corresponds to $0.40 \leq z_{HI} \leq 1.44$.

Under consideration for Phase 1: extending initial frequency band down to 0.90 GHz (i.e., $z_{HI} \rightarrow 0.58$, for an extra 1.1 Gyr and factor of ~2.5 in volume).

MeerKAT: site

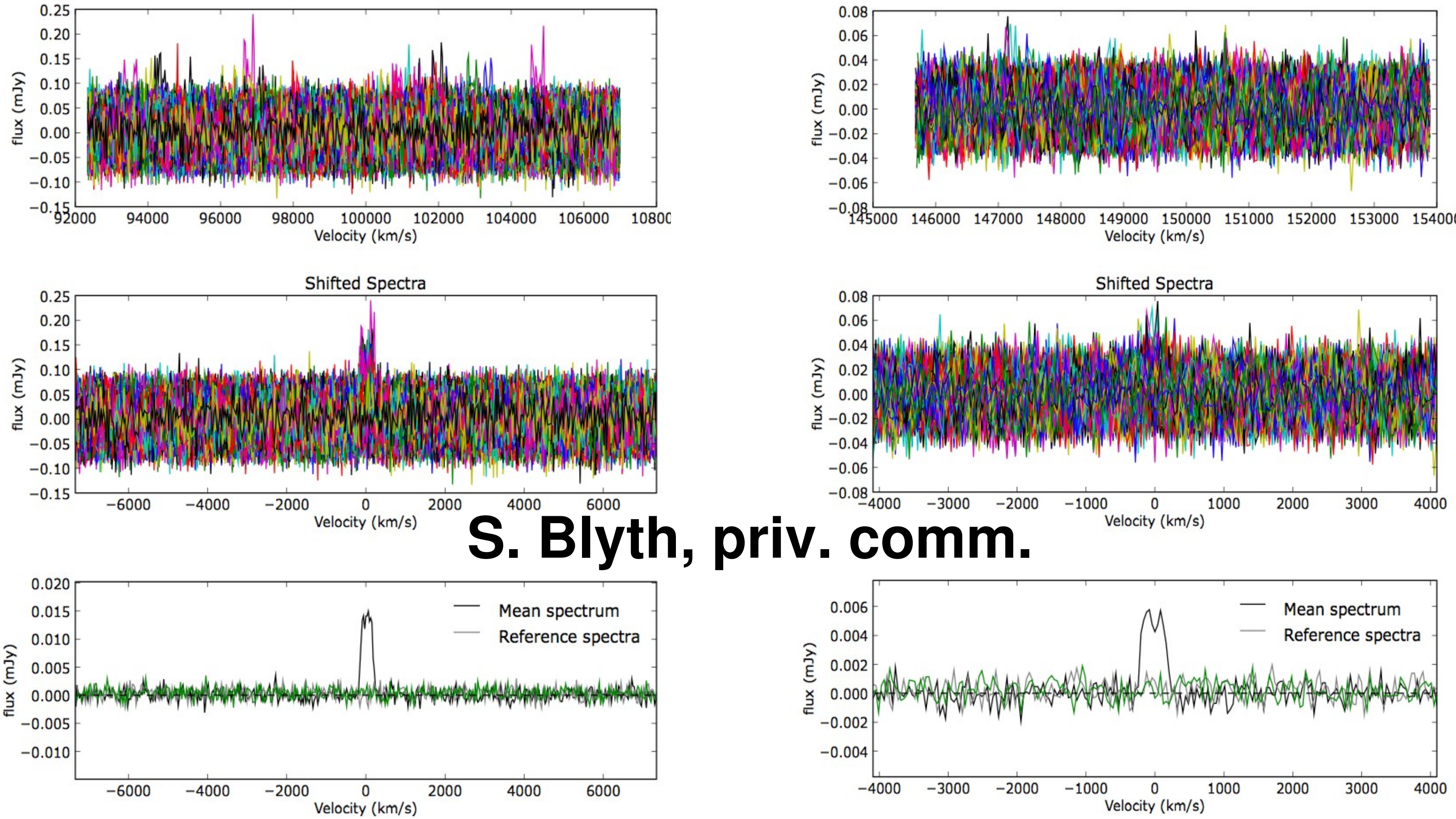
South African government has established a 12.5 million hectare radio astronomy reserve in the Northern Cape Province, centered on MeerKAT (≈ proposed SKA) site.

Also hosting C-BASS and PAPER.



LADUMA: stacking

Science will not be limited by nominal detection thresholds...



S. Blyth, priv. comm.

z = 0.5, 1000 hr, N = 1000 **z = 0.5, 4000 hr, N = 500**

Plans for spectroscopy

Spectroscopic redshifts will be sought through multiple avenues:

+ AAT/AAOmega (focusing on low-z line emitters)

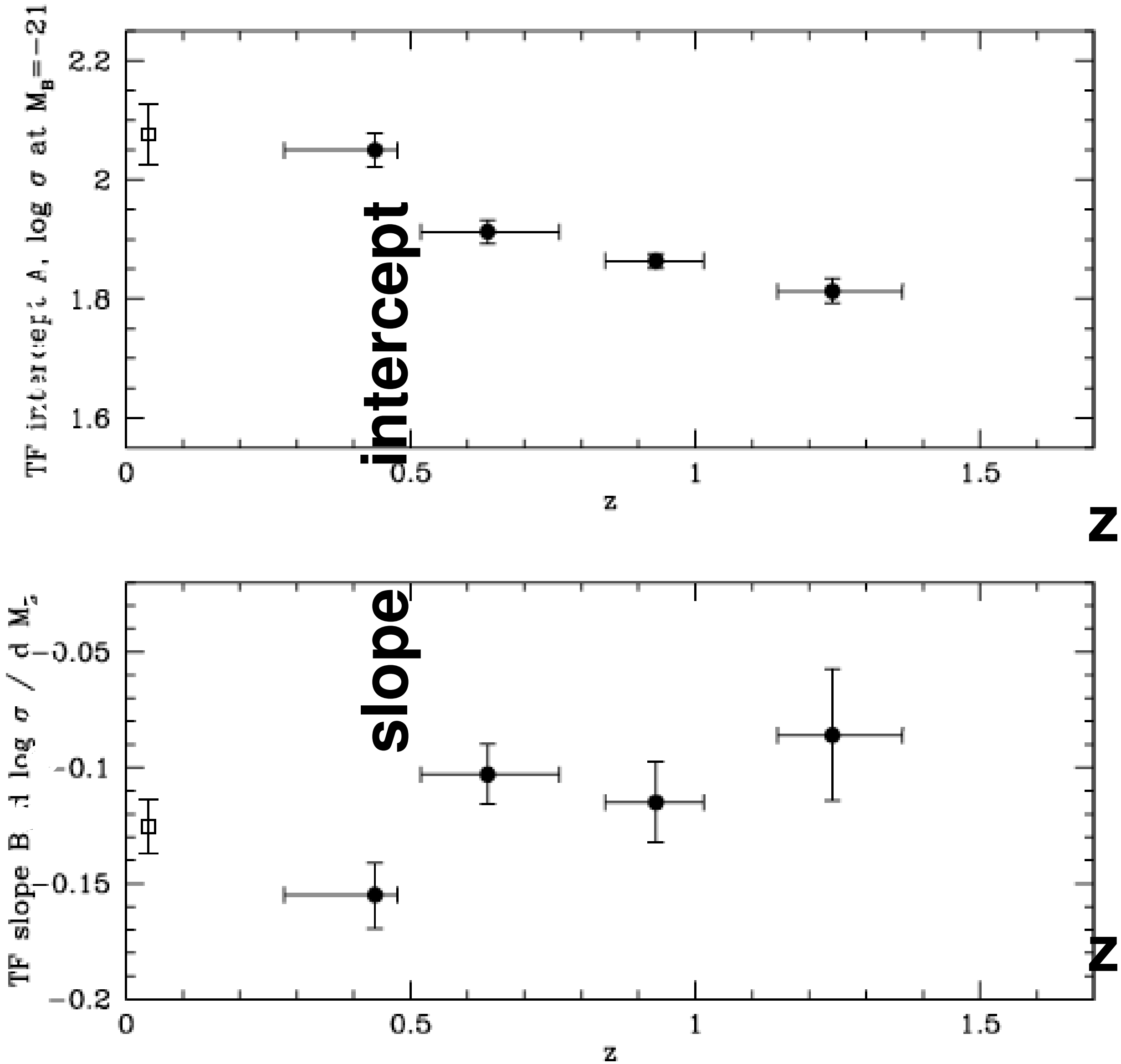
+ SALT/RSS

+ VLT/VIMOS

based on pre-imaging with SkyMapper, VISTA, DECam, etc.

If you would be interested in sharing data and/or slit masks for a highly spectroscopically complete survey of a few-deg^2 area encompassing the ECDFS area, let's talk!

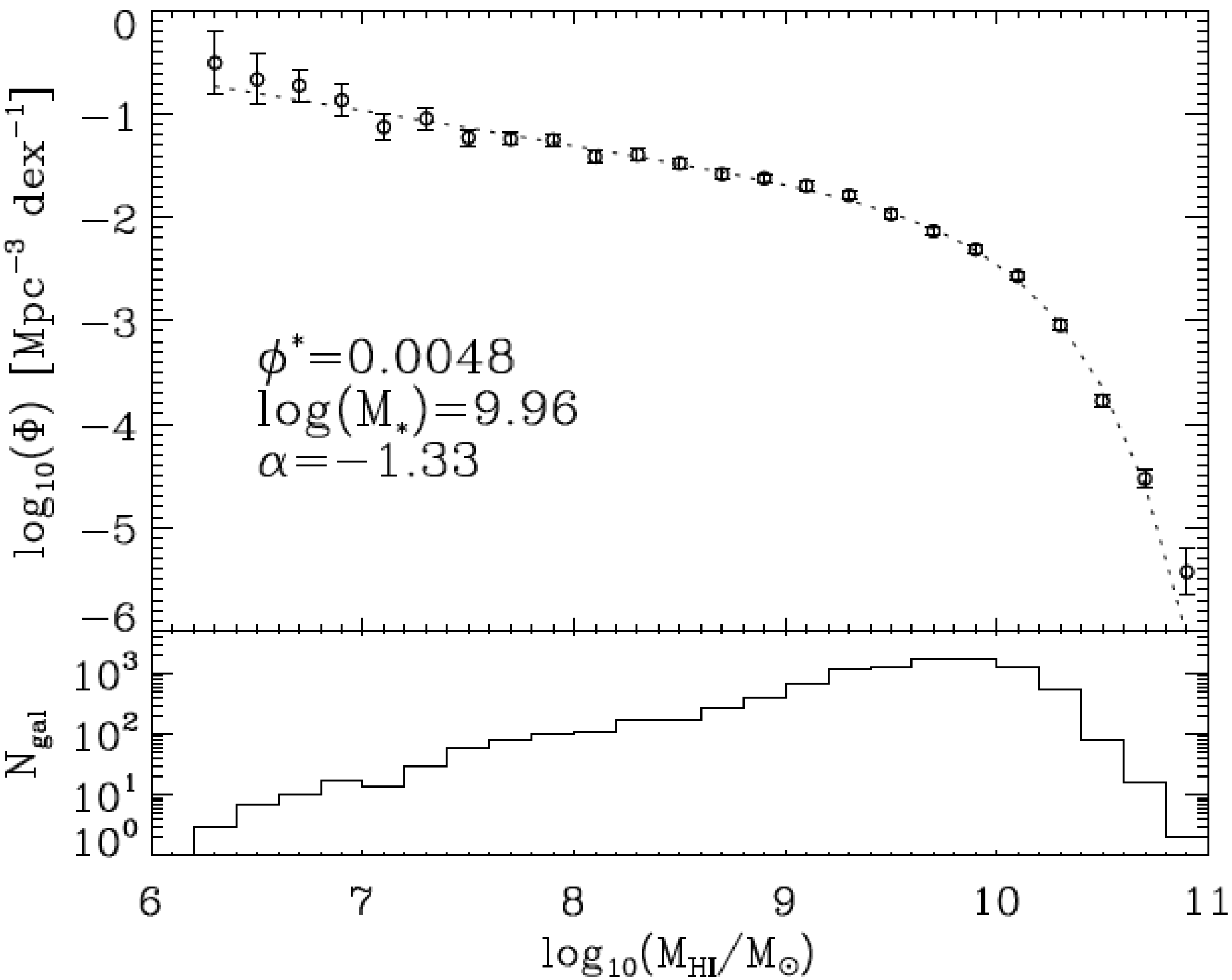
Science: Tully-Fisher evolution



How does baryonic Tully-Fisher relation evolves to $z \sim 1.4$?

Weiner et al. (2006), *B*-band Tully-Fisher

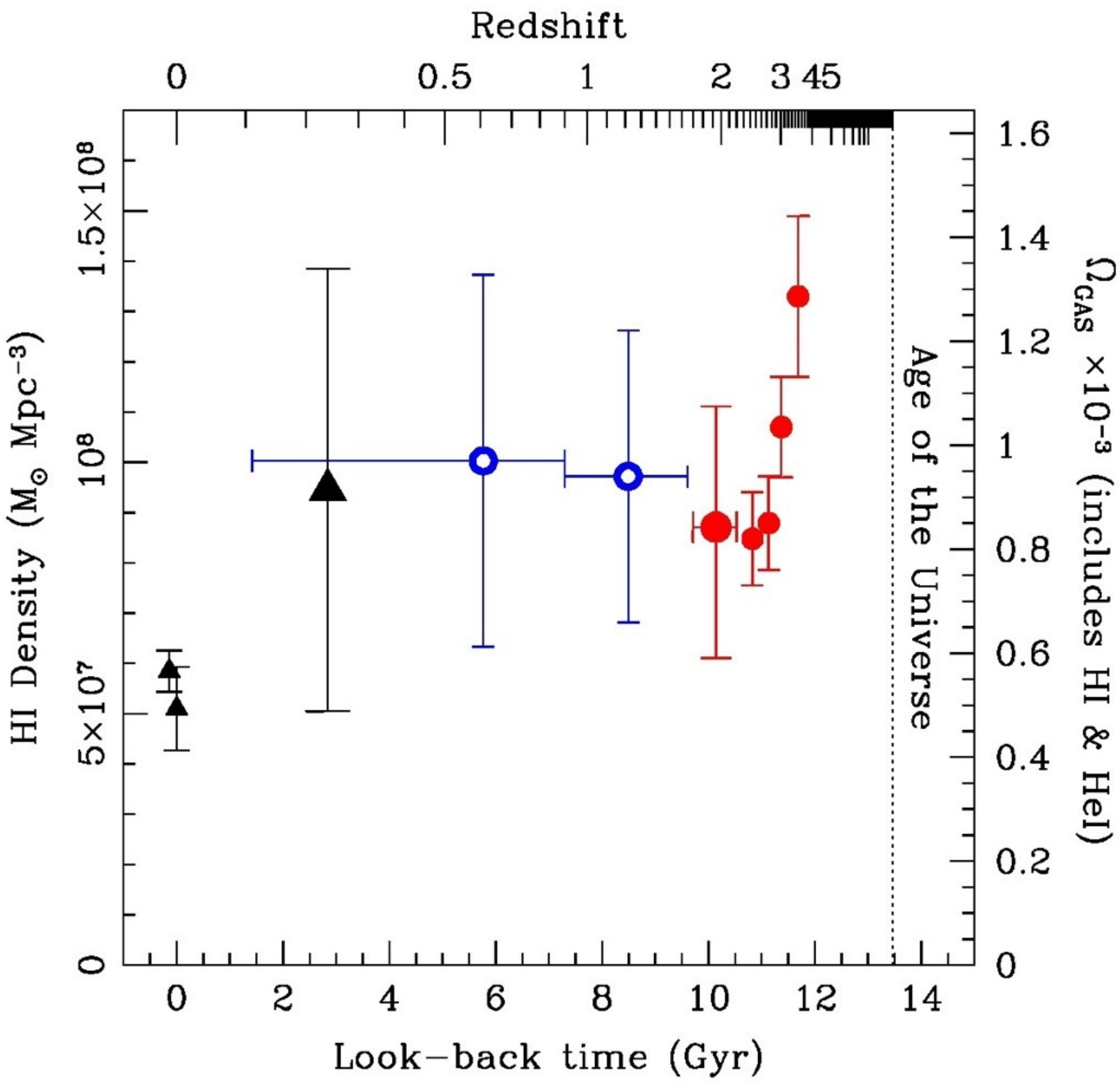
Science: HI mass function



How do parameters of HI mass function depend on redshift and environment?

Martin et al. (2010), *z* < 0.06

Science: cosmic HI density

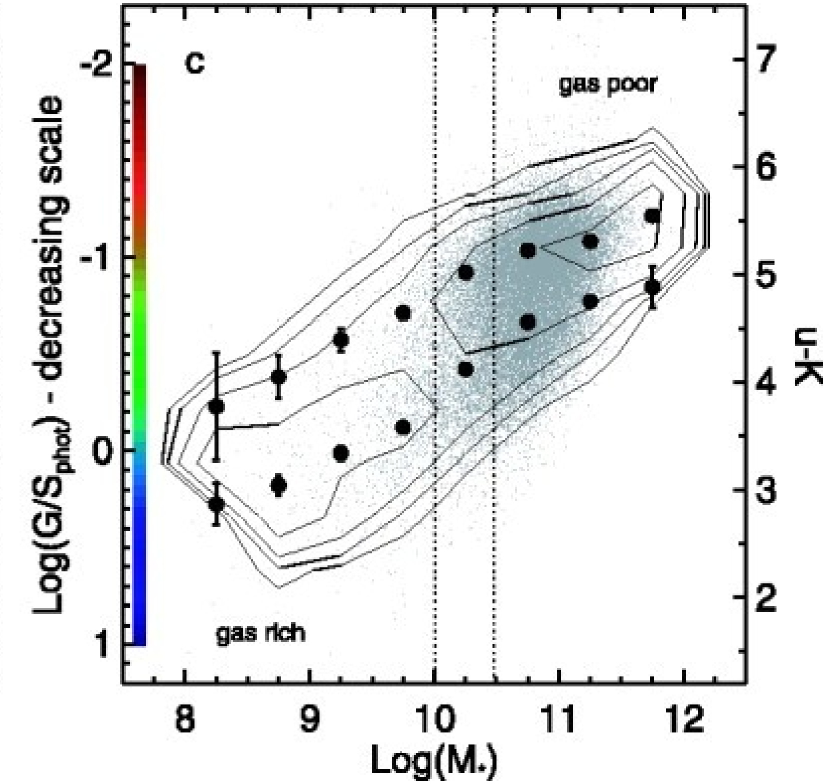


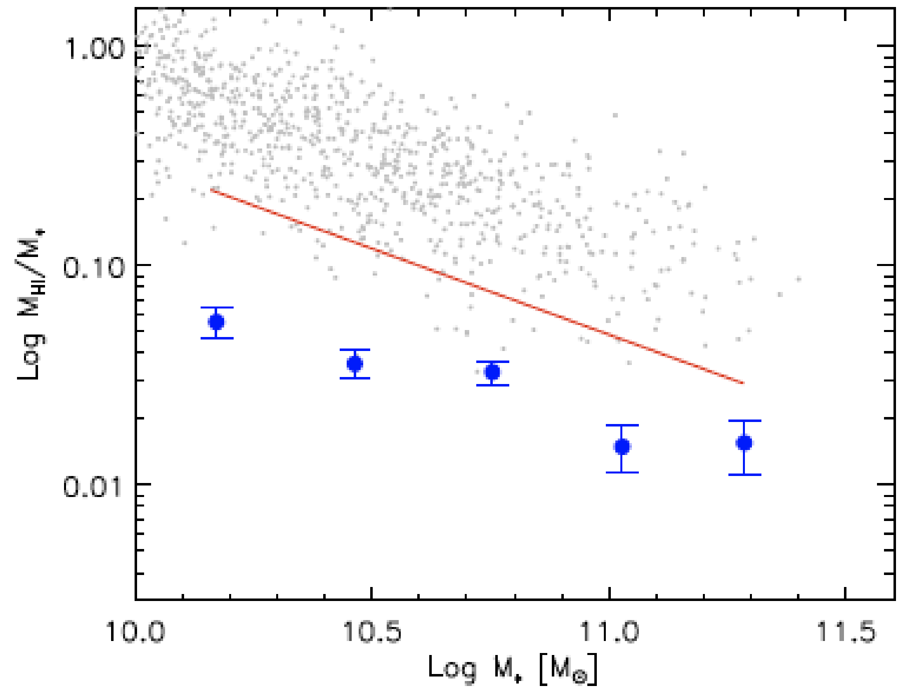
P. Lah (2011, priv. comm.)

What and where is Ω_{HI} as function of z?

HI emission vs. Lyα and MgII absorber comparisons over same Δz range will be extremely valuable.

Science: HI vs. galaxy property

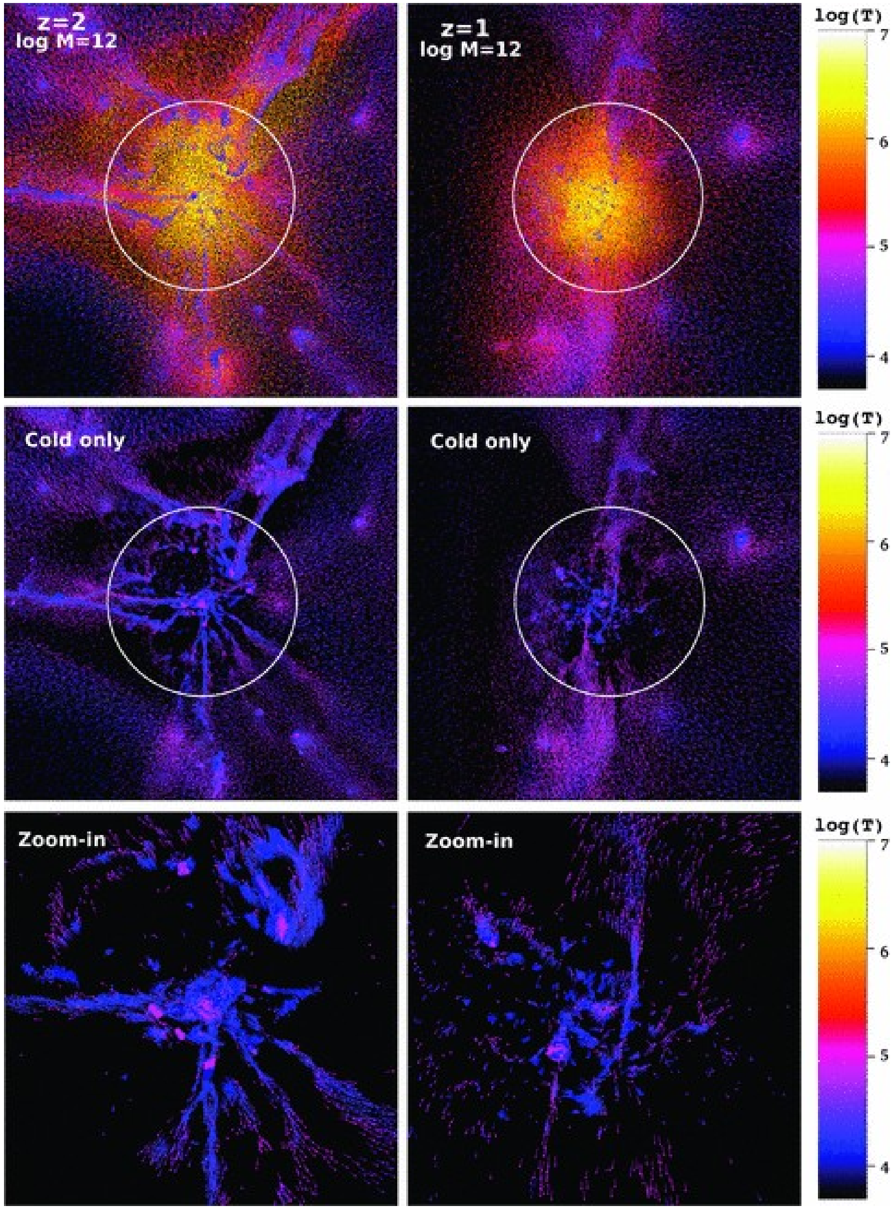




Kannappan (2004): gas/stellar mass fraction calibrated with *u-K* correlates with M^* at $z = 0$.

Fabello et al. (2010), stacking ALFALFA data: bulge-dominated galaxies have lower M_{HI}/M^* at fixed M^*.

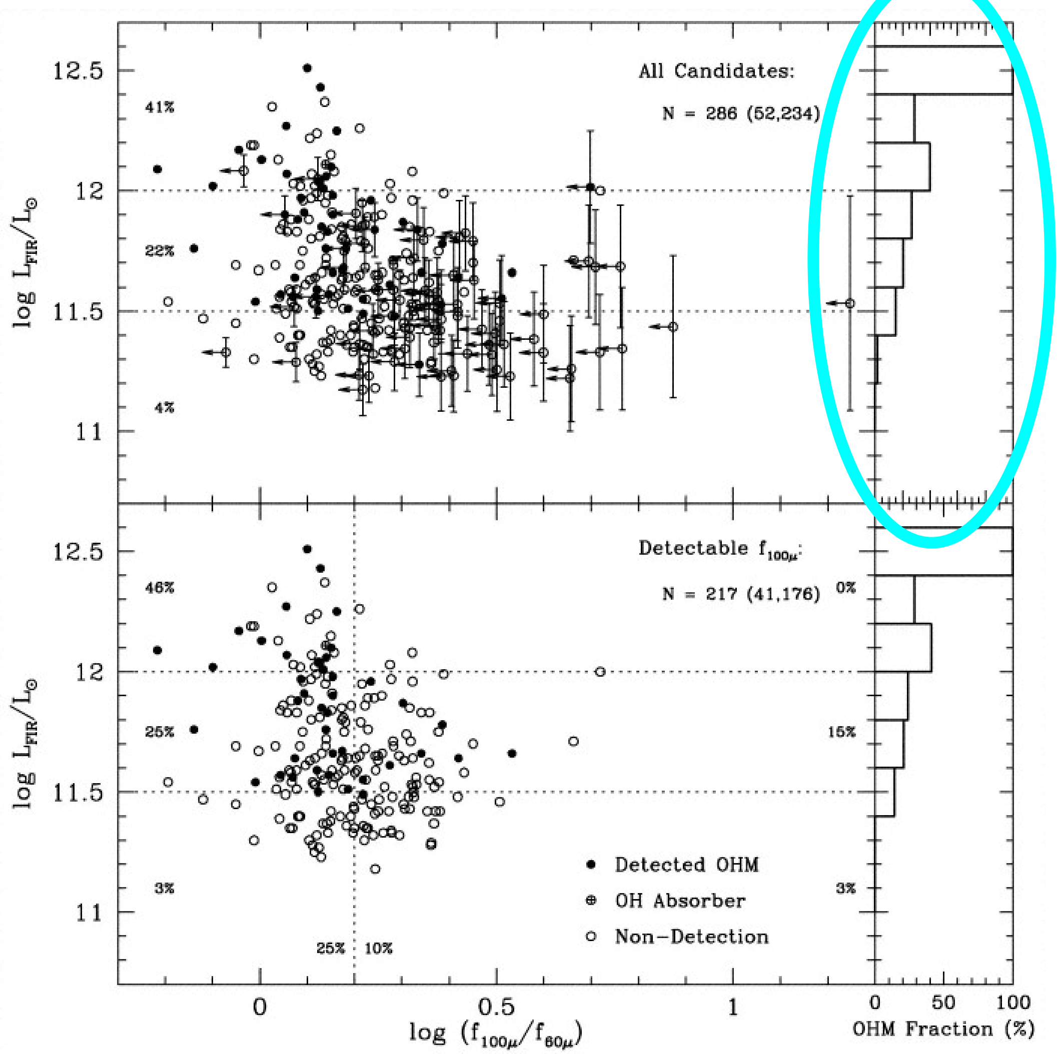
Science: HI vs. halo property



Kereš et al. (2010): simulations predict differences in hot/cold accretion based on halo mass and redshift.

Although clean tests are difficult, we can look for imprints of accretion mode on galaxies' HI contents.

Science: OH megamasers



OH megamaser galaxies "contaminate" HI samples, but provide an interesting view into cosmic history of galaxy mergers.

Darling & Giovanelli (2002)

Cosmic variance?

Do we need to worry that we are only observing one field?

NO!

We just need to sample/stack in volumes whose comoving dimensions exceed typical correlation lengths. For example, $\Delta z = 0.015$ at $z = 0.5$ defines a comoving volume > 48 Mpc in each dimension, >> few-Mpc r_0.

KAT-7 is already a reality!

KAT-7 (using deprecated dish design) has been completed on schedule at MeerKAT site; now taking science data.

Projected schedule

2015: Initial Phase 1 observations with partial array.

2016+: Phase 1 observations with full array.

2017+: Phase 2 observations with full array.

Before 2016: concentrate on developing ancillary data (spectroscopic redshift samples), theoretical modelling, source extraction/stacking software functionality, etc.

Commensality with other surveys

LADUMA is a team player! Data will be shared with several other approved surveys...

- **+ MALS (absorption-line survey)**
  PIs N. Gupta (ASTRON) & R. Srianand (IUCAA)
- **+ MIGHTEE (continuum survey)**
  PIs = M. Jarvis (UWC/Herts) & K. van der Heyden (UCT)
- **+ THUNDERKAT (transient survey)**
  PIs = R. Fender (Southampton) & P. Woudt (UCT)

...and will ultimately emerge in a series of public releases.

Summary

Surveys with ASKAP, Apertif, and EVLA will be able to generate vast HI samples out to $z \sim 0.4$ over the next few years.

LADUMA survey with MeerKAT will be able to push out to $z \sim 1.4$ beginning in ~2017 (to lower z starting 2015–16).

Scientific promise is vast, but will only be realized if we are not limited by shortage of spectroscopic redshifts!